

REPAIR BOND STRENGTH OF RESIN-MODIFIED RESTORATIVE GLASS IONOMER CEMENTS

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تتطلب أحيانا حشوات مادة «الجلالاس ايونومر» عند عنق السن إصلاح أو تصميها لشكلها الخارجي وذلك بعمل إضافات لها باستخدام المادة نفسها والمتوفرة عند طبيب الأسنان وقت الإصلاح والتي قد تكون من نفس النوع أو من أنواع أخرى من نفس المادة.

وقد كان الغرض من هذه الدراسة هو بحث تأثير ثلاثة عوامل على قوة الالتصاق الناتجة عن إصلاح مادة «الجلالاس ايونومر» المعدلة بإضافة الراتنج، حيث اشتملت هذه العوامل على عمر الحشوات عند الإصلاح، وكذلك استخدام نفس النوع أو أنواع أخرى من نفس المادة لعمل الإصلاح، وأيضا المعالجة السطحية للحشوات المراد إصلاحها.

وقد استخدمت ثلاثة أنواع من مادة الحشو «الجلالاس ايونومر» ذات التصلب الضوئي في تصنيع عينات أسطوانية تتكون كل منها من نصفين متساويين.

ولمحاكاة إصلاح الحشوات المعمرة، فقد تم تصنيع النصف الأول لكل العينات الأسطوانية وبلمرتها، ثم غمرها في الماء عند 37 درجة مئوية لمدة شهر وعند ذلك قسمت تلك العينات إلى مجموعتين متساويتين حيث تمت معالجة أسطح العينات بطريقتين مختلفتين. وبعد ذلك تم إكمال العينات الأسطوانية ببناء النصف الثاني لكل منها على السطح المعالج للنصف الأول وذلك باستخدام نفس النوع أو أنواع أخرى من نفس المادة. بعد ذلك تم تحديد قوة الالتصاق باستخدام اختبار القص.

Repair or correction of a glass ionomer cement (GIC) restoration contour would occasionally require additions to an existing restoration using the available GIC which could be the same or a different brand. Three brands of light-cured restorative GICs were used to fabricate cylindrical specimens consisting of two equal halves each. To simulate repair of aged restorations, specimens first halves were fabricated and then aged in water at 37°C for one month. They were divided into two groups for surface treatment for 15 sec using 25% polyacrylic acid in one group and a slurry of pumice on a rubber cup in the other group. Specimens "second halves were then built up against the treated surfaces using combinations of GICs. To simulate immediate repair, the specimens second halves were immediately built up of the same GIC against untreated surfaces of the first halves. Specimens simulating unrepaired restorations were fabricated and used as controls. Shear bond strengths were determined using universal testing machine after storage of all specimens in water at 37°C for one hour. Results showed, in general, a slight decrease in repair bond strength of GICs compared to the cohesive strength of unrepaired ones. Shear bond strengths of immediate repairs were higher than those for repaired aged GICs, and significantly higher for one brand. No significant differences in shear strength were found among the repaired aged GICs when brand combinations and surface treatments were used. The objective of this study, therefore, was to investigate the effect of repair time, GIC brand combination and surface treatment on the repair bond strength of resin-modified restorative GICs.

Introduction

Glass ionomer cements have received much attention since their introduction to the dental profession in 1972. They provide clinical dentistry with many advantages such as fluoride release¹, adhesion⁴, and adequate biocompatibility when used in the restorative form⁵. However, the strength of glass ionomer cements⁶, as well as their very low fracture resistance⁷ severely limit their application to areas of low stress or abrasion.

Several attempts at improving the properties of glass ionomer cements have been recorded in the literature which include the addition of inorganic^{8,11} or organic components to glass ionomers or polyacrylates. Organic additives, such as vinyl monomer, have been used to reduce catastrophic failure due to brittleness and improve wear resistance¹².

Recently, several manufacturers have developed resin-modified glass ionomer restorative materials that are hybrids of both conventional glass ionomer cements and visible light-activated composite resins. Loss of contour of existing conventional glass ionomer cervical restorations as a result of their continued erosion or abrasion has been reported.¹³ In vitro repair by addition of available conventional glass ionomer, which could be the same or unlike brand, has been investigated and appeared to be possible.^{14,18}

Few studies on the new resin-modified glass ionomer restorations, determining their physical properties or clinical performance, have been published. It was the objective of this study to investigate the effect of repair time, glass ionomer brand combination and surface treatment on the repair bond strength of resin-modified glass ionomer restoratives.

Received 10/04/96; revised 07/09/96, accepted 20/10/96

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Materials and Methods

Three different brands of encapsulated resin-modified glass ionomer restoratives were used in this study and are presented in Table 1. By strict definition, Dyract-PSA might be classified as modified composite or fluoride releasing resin

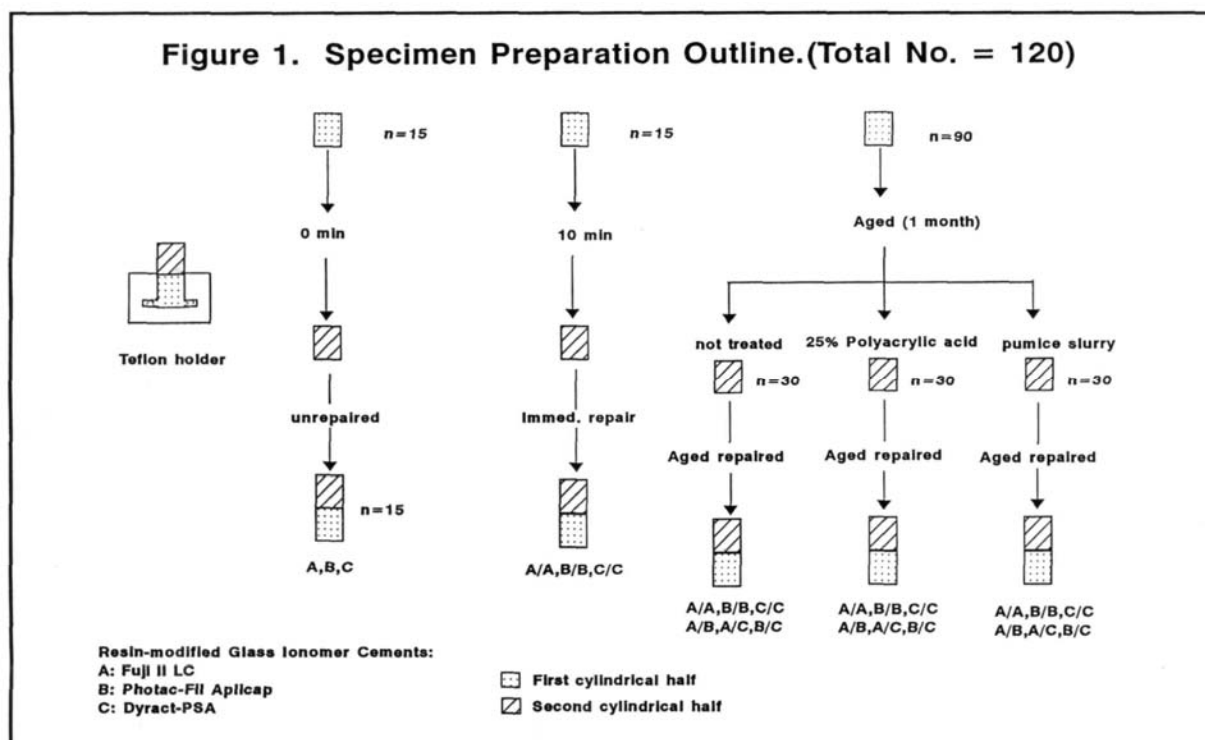
Table 1. The investigated resin-modified glass ionomer restoratives.

| Brand | Manufacturer |
|---------------------|--|
| Fuji II LC Capsules | GC America, Chicago, IL, USA |
| Photac-Fil Aplicap | ESPE-Premier Corp. Norristown, PA, USA |
| Dyract - PSA | DeTrey/Dentsply, Weybridge, UK |

rather than as resin-modified glass ionomer. While recognizing the controversy over nomenclature, a single term is used in this paper for simplicity.

A total of 120 cylindrical specimens, each consisting of two equal halves, were used in this study. The specimen first halves (8 mm in diameter, 4 mm long) were fabricated in undercut cavities prepared into one end of teflon cylindrical holders. All glass ionomer materials were used according to the respective manufacturer's instructions. The materials were injected directly into the cavities in 1 mm increments and gently packed. Then each increment was light-cured for 40 seconds using PolyLite 1000* visible light-curing unit. The last increment was light-cured in contact with a plastic strip to ensure that the surface was smooth and parallel to the bottom of the teflon holder. The specimen's first halves were randomly divided into three groups. Five cylindrical specimens of each brand or a combination of two brands were prepared in each group. In the first group (n=15) of unrepaired specimens, a new material of the same brand was added to the untreated surface of specimen first half after 10 minutes of first half fabrication.

Whereas in the third group (n=90) of repaired aged specimens, the specimen's first halves were aged by storage in water at 37°C for one month, then they were randomly divided into three subgroups of 30 each. Surfaces of specimen's first halves in subgroup one received a surface treatment of 1 15-second swab with 25% polyacrylic acid (PAA). While those in subgroup two were treated by a 15-second scrub with fine pumice and water slurry on a webbed rubber cup using slow speed. No surface treatment was done to the specimen's first halves in subgroup three. All treated surfaces were then rinsed with water for 45 seconds and dried for 15 seconds with oil-free compressed air. In all subgroups, new materials of the same or unlike brand were added to the specimen's first halves. Additions of new materials in all groups were made in 1 mm increments using split cylindrical teflon molds (8 mm inside diameter, 4 mm long). These split molds were placed perpendicular to the surface of the specimen's first halves. Contrasting shades of materials used for fabrication of the specimen's first and second halves were used so that the repair interface could be easily identified. The specimen preparation conditions are outlined in Figure 1. Specimens in all groups were stored in distilled water at 37°C for 24 hours before testing. The shear bond strengths at the interface were determined for all specimens. The specimens were each mounted in the Universal Testing Machine** using especially designed grips. Each mounted specimen was sheared at the repair interface using a unibevelled steel blade. The load range was 0-200 kg and crosshead speed was 0.5 mm/min.



* Pro-Den System, Inc., Portland, Oregon, USA.

** Lloyd Instruments, Ltd., Segenswarth W. Fareham, England.

Data were analyzed using a two-way analysis of variance (ANOVA) and a Student-Newman-Keuls test, followed by Student's *Mest*. Following shear bond strength testing, fractured parts of all repaired specimens were examined using a stereomicroscope at 10x magnification to determine the failure mode. Fractures occurring within the specimen's halves were counted as cohesive failure, whereas adhesive failure denoted fractures occurring at the repair interface. A combination of cohesive and adhesive fractures was considered as a mixed mode of failure.

Results

Repair bond strengths of all specimens were calculated. Mean values are listed in Tables 2 and 3. For all the three resin-modified glass ionomer restoratives when repaired using the same brands, the following findings were obtained (Table 2, Fig. 2). A reduction in shear strength of immediate repairs was observed when compared to the cohesive strength of the

unrepaired specimens and was not significant ($t=2.65, P>0.05$).

The results of this study showed a decrease in shear bond strengths of specimens with no surface treatment after ageing compared to those of immediate repair. This decrease was significant for Dyract-PSA ($t=3.82, P<0.05$). In addition, bond strength of repairs after ageing was affected by surface treatments in all materials, where pumice slurry-treated specimens exhibited an increase in bond strengths compared to those of untreated specimens and a significant increase ($F=3.47, P<0.05$) in bond strengths compared to those of PAA-treated specimens.

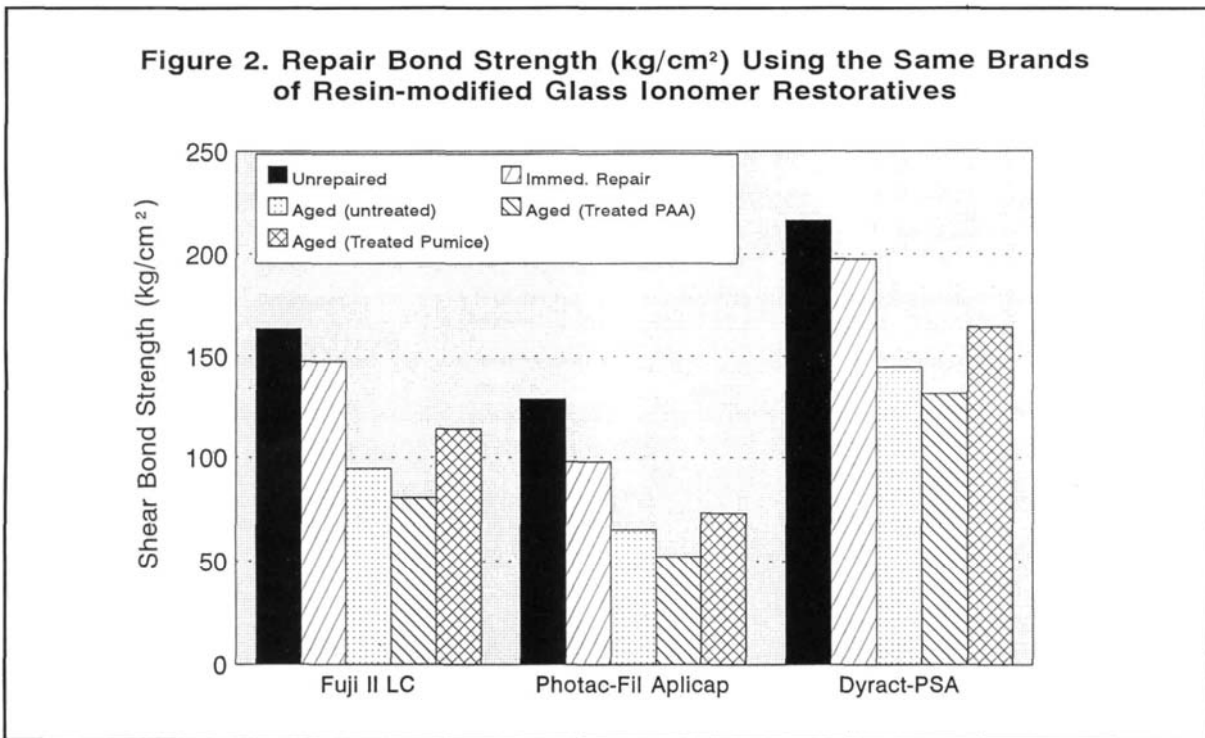
Shear bond strength of repaired specimens for the same specimens of investigated GI restoratives were lower than their cohesive shear strengths. It was found that the decreased repair bond strengths were significantly different for Dyract-PSA ($F=2.74, P<0.05$).

For the three combinations of unlike brands of materials investigated, the repair bond values of treated aged specimens

Table 2. Repair bond strength (kg/cm²) using the same brands of resin-modified glass ionomer restoratives.

| Brand | Unrepaired | Immed. (Untreated) | Aged (Untreated) | Aged (Treated) | |
|--------------------|-------------|---------------------------|---------------------------|---------------------------|---------------------------|
| | | | | PAA | Pumice Slurry |
| Fuji II LC | 163.4(26.7) | 147.3(34.1) | 84.6(11.2) | 80.6 ^b (4.4) | 113.9 ^b (15.9) |
| Photac-fil Aplicap | 128.5(15.8) | 97.9(3.7) | 65.3 (3.5) | 52.3 ^a (9.2) | 73.2 ^b (5.1) |
| Dyract - PSA | 216.3(59.1) | 197.6 ^c (27.1) | 144.7 ^c (28.4) | 131.1 ^b (18.8) | 164.3 ^a (31.9) |

- a: Mean (SD)
- b: Significant difference between aged treated specimens/brand at P < 0.05.
- c: Significant difference between aged treated specimens/brand at P < 0.05.



ranged from as low as 41.6 kg/cm² for Fuji II LC/Photac-Fil Aplicap repairs when treated with 25% polyacrylic acid to a high of 156.8 kg/cm² for Fuji II LC/Dyract-PSA when treated with a slurry of pumice. No significant difference in shear bond strength was found between untreated and treated aged specimens. Aged specimens treated with pumice attained a significantly higher bond strength than those treated with 25% polyacrylic acid (P<0.05). The repair bond strengths obtained

for unlike brands were not significantly different (P>0.05) from those obtained for the same brands (Table 3).

The modes of failure of specimens repaired using the same and unlike brands of resin-modified glass ionomer restoratives are given in Tables 4 and 5, respectively. For the majority of the specimens (46/60 Table 4 and 34/45 Table 5), the mode of failure was adhesive. Only 14 cohesive failures were noted, whereas 11 specimens showed a mixed mode of failure.

Table 3. Repair bond strength (kg/cm²)³ of aged specimens using combinations of unlike brands of resin-modified glass ionomer restoratives.

| Brand | Unrepaired | Immed. (Untreated) | Aged (Untreated) | Aged (Treated) | |
|----------------------------------|-------------|---------------------------|---------------------------|---------------------------|---------------------------|
| | | | | PAA | Pumice Slurry |
| Fuji II LC / Photac-fil Aplicap | 163.4(26.7) | 147.3(34.1) | 84.6(11.2) | 80.6 ^b (4.4) | 113.9 ^b (15.9) |
| Fuji II LC / Dyract - PSA | 128.5(15.8) | 97.9(3.7) | 65.3 (3.5) | 52.3 ^b (9.2) | 73.2 ^b (5.1) |
| Photac-fil Aplicap/ Dyract - PSA | 216.3(59.1) | 197.6 ^c (27.1) | 144.7 ^c (28.4) | 131.1 ^b (18.8) | 164.3 ^b (31.9) |

a : Mean (SD)

b : Significant difference between aged treated specimens/brand at P < 0.05.

c : Significant difference between aged treated specimens/brand at P < 0.05.

Table 4. Modes of failure of specimens repaired using the same brands of resin-modified glass ionomer restoratives.

| Brand | Condition | Failure Type (Frequency) | | |
|--------------------|--------------------|--------------------------|------------|----------|
| | | Cohesive* | Adhesive** | Mixed*** |
| Fuji II LC | Immed. (Untreated) | 1 | 3 | 1 |
| | Aged (Untreated) | 1 | 4 | 0 |
| | Aged/PAA | 0 | 5 | 0 |
| | Aged/Pumice | 0 | 4 | 1 |
| Photac-Fil Aplicap | Immed. (Untreated) | 1 | 4 | 0 |
| | Aged (Untreated) | 1 | 4 | 0 |
| | Aged/PAA | 0 | 4 | 1 |
| | Aged/Pumice | 0 | 5 | 0 |
| Dyract - PSA | Immed. (Untreated) | 2 | 3 | 0 |
| | Aged (Untreated) | 1 | 4 | 0 |
| | Aged/PAA | 1 | 3 | 1 |
| | Aged/Pumice | 1 | 3 | 1 |

* Failures occurring within specimen halves.

** Failures occurring at repair interface.

*** A combination of adhesive and cohesive failures.

Table 5. Modes of failure of specimens repaired using the same brands of resin-modified glass ionomer restoratives.

| Brand Condition | Surface Treatment | Failure Type (Frequency) | | |
|----------------------------------|-------------------|--------------------------|------------|----------|
| | | Cohesive* | Adhesive** | Mixed*** |
| Fuji II LQ Photac-Fil Aplicap | Untreated) | 2 | 2 | 1 |
| | 25 % PAA | 1 | 3 | 1 |
| | Pumice | 0 | 4 | 1 |
| Fuji II LC/ Dyract - PSA | Untreated) | 0 | 5 | 0 |
| | 25 % PAA | 0 | 5 | 0 |
| | Pumice | 0 | 5 | 2 |
| Photac-Fil Aplicap/ Dyract - PSA | Untreated) | 1 | 4 | 0 |
| | 25 % PAA | 1 | 3 | 1 |
| | Pumice | 0 | 5 | 1 |

* Failures occurring within specimen halves.

** Failures occurring at repair interface.

*** A combination of adhesive and cohesive failures.

Figure 3. Repair Bond Strength (kg/cm²) of Aged Specimens Using Combinations of Unlike Brands of Resin-modified Glass Ionomer Restoratives (25% PAA Surface Treatment)

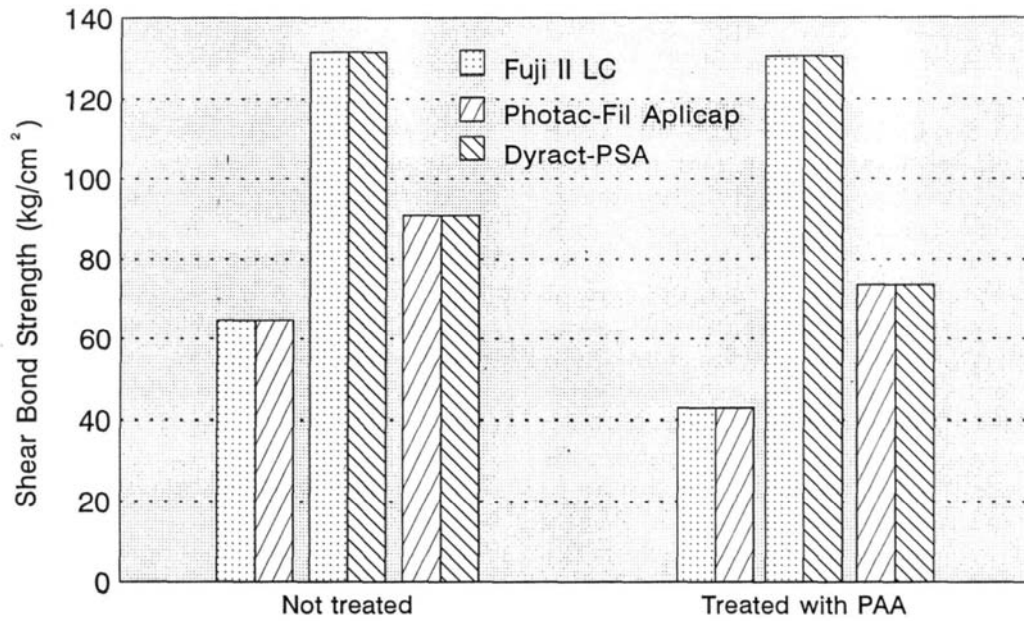
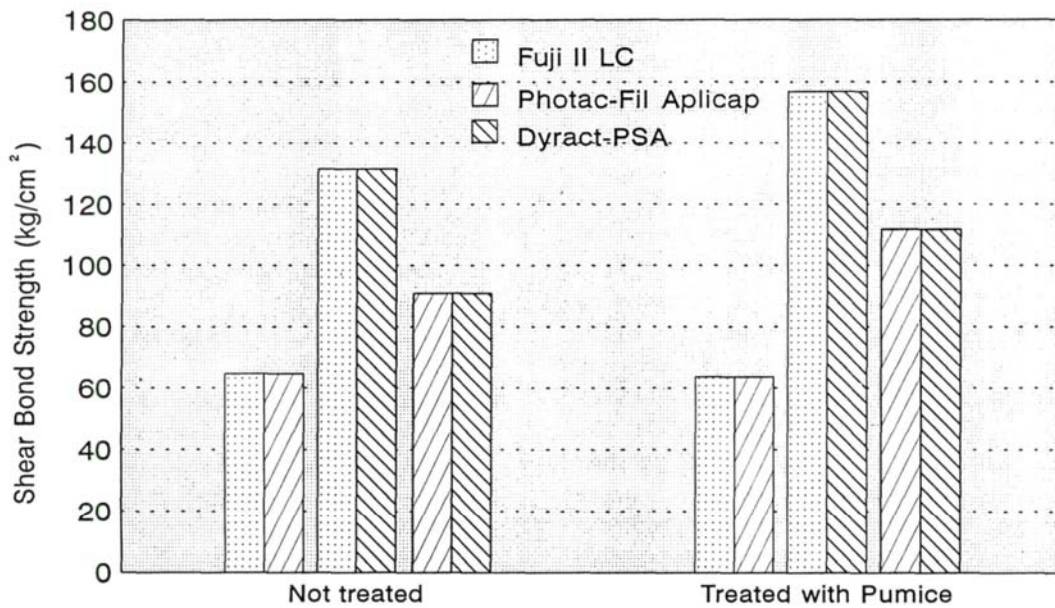


Figure 4. Repair Bond Strength (kg/cm²) of Aged Specimens Using Combinations of Unlike Brands of Resin-modified Glass Ionomer Restoratives, (Slurry of Pumice Surface Treatment)



Discussion

In clinical situations, immediate repair of direct restorative materials, including the resin-modified glass ionomer restoratives, is sometimes necessary after initial placement of such restorations. Among these situations are overfinishing, fracture and lack of contour as well as surface voids.

Comparison of the findings of this study with those of the conventional glass ionomer restoratives^{14,18} revealed interesting results because of the substantial differences between the conventional and resin-modified glass ionomer restoratives. In this study, the shear bond strengths of immediate repairs were found to be higher than those for repair of aged specimens. This finding is consistent with the results of other researchers.^{15,18}

In the present study, ageing by water storage prior to repair was found to adversely affect the repair bond strengths. Storage in water may have resulted in deterioration of the cohesive strength of these materials. This finding is consistent with that of those studies,^{19,20} which reported a significant reduction in compressive strength of resin-modified glass ionomers after storage in water. These studies have also concluded that the resin-modified glass ionomers contain a high proportion of hydrophilic functional groups after their photochemical activation. Furthermore, it has been pointed out that the resulting structure resembles that of a synthetic hydrogel, which by its design is intended to absorb moisture and generally have low mechanical strengths.^{19,20}

Treatment of existing resin-modified glass ionomer restorations, prior to repair, is intended to clean their surfaces and remove the salivary pellicle covering such surfaces due to exposure to saliva. Removal of the salivary pellicle is necessary to obtain intimate contact and optimum cohesion between the existing and added materials.

In this study, surface treatment was found to have an effect on repair bond strength of aged specimens. The bond strengths of pumice-treated specimens were significantly higher ($P < 0.05$) than those of specimens treated with 25% polyacrylic acid when the same or unlike brands of resin-modified glass ionomer restoratives were used.

In addition to its noticeable action in providing better surface cleansing and more intimate contact required for improved cohesion, the stronger repair attained with the slurry of pumice may have occurred because of the mechanical interlocking of newly added materials into the possible micro-irregularities created by roughening the surface of existing materials with pumice slurry prior to repair. The lower repair bond strength obtained for surface treatments with 25% polyacrylic acid for 15 seconds prior to repair may have occurred because polyacrylic acid in 25% concentration and for a 15-second application did not make the existing surface of glass ionomer, particularly reactive. Polyacrylic acid might be effective in improving the bond strength of repair at concentrations higher than 25% and/or for application time longer than 15 seconds.

The repair accomplished with unlike brands of resin-modified glass ionomer restorative was not significantly different from that achieved with the same brands.

It should be noted that the great majority of failures observed in the present study was adhesive. An acceptable cohesion and micromechanical bond between an existing and a new resin-modified glass ionomer restoratives can be achieved when adequate wettability of the new material on the existing one is attained. This wettability is dependent on the viscosity of the new materials.¹⁹ Unfortunately, the observed viscosity of the investigated resin-modified glass ionomers appeared to prevent such an acceptable micromechanical bond.

Despite the fact that reparability of an existing resin-modified glass ionomer restoratives was found in this study to be enhanced by treatment of the aged surfaces with a slurry of pumice for 15 seconds, nevertheless, it is still suggested that retention of the extensive repair by adhesion of the new material to tooth structure be as well attempted.

Conclusion

Based on the results of this study, the following conclusions can be drawn :

1. Bonding of new resin-modified glass ionomer restoratives to previously placed ones can be achieved. However, the success of this procedure may vary among different brands of resin-modified glass ionomer used.
2. Immediately repaired specimens displayed higher bond strengths than those repaired after ageing for one month.
3. Specimens repaired by using a slurry of pumice surface treatment exhibited higher bond strengths than those repaired using 25% polyacrylic acid surface treatment.
4. The investigated glass ionomer restoratives showed a decrease in shear bond strengths of all repairs compared to their cohesive (unrepaired) shear strengths, where Dyract-PSA exhibited a significant decrease.
5. It is suggested that retention of new resin-modified glass ionomer restoratives to existing ones that need extensive repair be enhanced by adhesion of the new materials to tooth structure as well.

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